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ORIGINAL ARTICLE

What is harmful for male fertility: Cell phone or the wireless internet?

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Abstract In this study, we aimed to assess the potential harmful effects of radiofrequency-electromagnetic radiation on sperm parameters. We requested semen for analyses from the male patients coming to our infertility division and also asked them to fill out an anonymous questionnaire. We queried their mobile phone and wireless internet usage frequencies in order to determine their radiofrequency-electromagnetic radiation exposure. A total of 1082 patients filled the questionnaire but 51 of them were excluded from the study because of azoospermia. There was no significant difference between sperm counts and sperm morphology excluding sperm motility, due to mobile phone usage period, ($p = 0.074$, $p = 0.909$, and $p = 0.05$, respectively). The total motile sperm count and the progressive motile sperm count decreased due to the increase of internet usage ($p = 0.032$ and $p = 0.033$, respectively). In line with the total motile sperm count, progressive motile sperm count also decreased with wireless internet usage compared with the wired internet connection usage ($p = 0.009$ and $p = 0.018$, respectively). There was a negative correlation between wireless internet usage duration and the total sperm count ($r = -0.089$, $p = 0.039$). We have also explored the negative effect of wireless internet use on sperm motility according to our preliminary results.

Conflicts of interest: All authors declare no conflicts of interest.

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Introduction

Cell phone and wireless internet have become an indispensable part of our lives. Especially, after the development of smart phones and 3G internet technologies, the exposure to the radiofrequency (RF) electromagnetic radiation (EMR) has increased to terrifying levels. Cell phone and wireless technologies (Wi-Fi) operate from 850 MHz to 1800 MHz and ~2400 MHz; respectively [1,2]. Tissues can absorb RF-EMR in many ways including aerial effect and/or coupling the signal [3]. Previously, the harmful effects of RF-EMR on DNA integrity and on various organs such as the brain and heart have been very well described [4]. The World Health Organization (WHO) officially declared that cell phones can cause brain cancer [5]. After this declaration, usage of hands-free devices has increased but cell phones still remain close to the gonads of individuals that may result in infertility due to the harmful effects of RF-EMR.

Infertility is a common disorder that affects 15% of couples and nearly half of the cases are due to male infertility. As mentioned above, RF-EMR affects many organs including the testes by a direct or a thermal effect [6]. In one study, detrimental effects of RF-EMR on Leydig cells, seminiferous tubules, and especially the spermatozoa were clearly defined [1]. Although RF-EMR reduces testosterone levels, impairs spermatogenesis, and causes sperm DNA damage [4], the relationship between RF-EMR devices and male infertility is still controversial.

In the literature, the harmful effects of RF-EMR on male reproductive systems are shown in rats, however; human studies are very rare and can only be planned with a smaller population [4,7]. For instance, Agarwal et al [4] detected the negative effects of cell phones on sperm parameters in 361 men. Similarly, Fejes at al [7] showed the negative correlation between the daily cell phone usage duration and semen quality in 371 men. In this decade, wireless internet connection has been involved in our lives as much as cell phones with 3G technologies. As we all know, Wi-Fi connection transmits more RF-EMR than cell phones, so we examined the effects of both cell phone and wireless internet use on sperm parameters in healthy males in order to determine the possible harmful effects of RF-EMR devices.

Materials and methods

This study was performed under the approval of our Institutional Review Board in our university (Turgut Ozal University, Ankara, Turkey) (999500669/869), and informed consents were obtained from all patients. In our population based observational study, we collected data from 1082 healthy men who attended the Andrology subdivision of the Urology Department (Turgut Ozal University) between June 2013 and June 2014. Men with a history of orchitis, varicocele, diabetes mellitus, cardiac, neural disease, nephritic disease, and hypertension, or men who had a family history of any genetic disease were excluded from the study. In addition, patients who suffered from a viral/bacterial infection in the previous 4 weeks, had an *in vitro* fertilization history, or were already recruited to an intacytoplasmic sperm injection program were also excluded from the study. Azoospermic patients were excluded from the study. Semen samples were collected by masturbation in a sterile wide-mouthed calibrated container (Sigma, St. Louis, MO, USA) with the abstinence of ejaculation for a minimum of 2 days and no longer than 5 days before the semen collection. Semen analyses were performed according to the WHO guidelines that include eight sperm parameters: volume, liquefaction time, pH, viscosity, sperm count, motility, viability, and percentage of the normal morphology [8]. Assessments of semen analysis were performed at the end of the 30-minute period. Sperm motility was analyzed by using a phase-contrast microscope (Nikon, Alphaphot-2, YS-2, Tokyo, Japan) with $> 20\times$ magnification. Semen analyses were performed by two experienced and blinded operators. Motility and concentrations of semen were evaluated by using a Makler counting chamber (Sefi-Medical Instrument, Haifa, Israel). WHO criteria (4 categories of sperm movement; A: rapid progressive, B: slow progressive, C: nonprogressive, and D: no motility) were used in the assessment of sperm movement. Azoospermic patients and the patients whose sperm counts were < 5 million/mL were excluded from the study due to possible factors such as genetic, testicular hypofunction, or idiopathic. An anonymous questionnaire including (1) daily the cell phone usage duration, (2) habits of carrying mobile phone, (3) wireless internet usage duration, and (4) type of internet usage. According to an anonymous questionnaire, daily active cell phone usage was divided into three groups as following: Group A, < 30 min/d; Group B, from 30 min/d to 2 h/d; and Group C, > 2 h/d. Habits of carrying a mobile phone was recorded as (A) in the pocket of trousers, (B) in a handbag, or (C) in the pocket of jackets. Wireless internet usage was divided in to three groups, Group A: < 30 min/d; Group B, from 30 min/d to 2 h/d; and Group C, > 2 h/d. Internet usage types recorded as wireless or not. Body mass index and annual smoking habits (at least 10 cigarettes a day) were also recorded. Because of the high number of participants we could not ask about the cell phone models but we know that all of the cell phones operate between the 850—1800 Mhz in our country.

Correlation between the eight sperm parameters was evaluated by the determination of the Pearson correlation coefficients. Data were presented as mean $\pm$ standard deviation. Statistical analyses were performed by using Student t test (2-tailed) and one way analysis of variance (ANOVA). SPSS for Windows (version 16.0; SPSS Inc., Chicago, IL, USA) was used for statistical analyses and $p < 0.05$ was considered as statistically significant.

Results

Fifty-one azoospermic patients were excluded from the study, and the data of 1031 patients were collected. The average age of the participants was 30.9 $\pm$ 6.2 (18—63) years. The average body mass index of participants was 26.8 $\pm$ 3.9 (14.9—46.24). Smoking rate was 352/1031 participants. Of those men, the average smoking duration was 9.94 $\pm$ 5.64 (2—35) years.

Table 1 Comparison of the demographic data and sperm parameters among the duration of cell phone usage groups.

	< 30 min (n = 382)	30 min–2 h (n = 286)	> 2 h (n = 363)	p*
Age (y)	32.3 ± 6.63	30.8 ± 5.74	29.5 ± 5.84	0.059
BMI (kg/m^2)	26.1 ± 3.7	26.5 ± 3.4	26.5 ± 4.2	0.132
Smoking (y)	3.96 ± 6.37	2.52 ± 4.91	3.47 ± 5.59	0.021
Volume	2.9 ± 1.41	2.9 ± 1.19	3.01 ± 1.45	0.194
TSC (million)	42.3 ± 16.3	39.2 ± 16.3	37.8 ± 16.1	0.074
TMS (million)	61.1 ± 60.6	54.6 ± 50.6	53.8 ± 59	0.05
PMS (million)	47.5 ± 50.8	42.5 ± 42.1	41.6 ± 51.2	0.083
Morphology	2.8 ± 1.9	2.57 ± 1.76	2.74 ± 1.72	0.909

*One way analysis of variance was performed. A p value < 0.05 between all groups was considered significant.
BMI = body mass index; PMS = progressive motile sperm count; TMS = total motile sperm count; TSC = total sperm count.

Table 3 Comparison of the demographic data and sperm parameters among the duration of wireless internet usage groups.

	< 30 min (n = 327)	30 min–2h (n = 164)	> 2 h (n = 540)	p*
Age (y)	30.9 ± 6.77	31.1 ± 5.9	30.8 ± 5.9	0.023
BMI (kg/m^2)	25.8 ± 3.5	26.8 ± 3.7	26.5 ± 4.1	0.157
Smoking (y)	4.23 ± 6.51	2.45 ± 5.08	3.16 ± 5.38	0.017
Volume	2.99 ± 1.4	2.81 ± 1.32	2.99 ± 1.36	0.43
TSC (million)	43 ± 33	41.8 ± 28.2	37.4 ± 29.4	0.093
TMS (million)	61.7 ± 60.2	56.2 ± 57.5	53.8 ± 57.5	0.032
PMS (million)	48.2 ± 53.7	43 ± 42.1	41.8 ± 49.6	0.033
Morphology	2.73 ± 1.84	2.65 ± 1.75	2.73 ± 1.85	0.305

*One way analysis of variance was performed. A p value < 0.05 between all groups was considered significant.

Duration of cell phone use

According to our results, there was no significant difference between these three groups regarding sperm parameters such as semen volume, sperm count, total motile sperm count, progressive motile sperm count, and morphology of the sperm. However, there was a significant correlation between smoking which has a significantly shorter duration in Group B than the other groups (p = 0.022; Table 1).

Mobile phone carrying habits

There was a significant difference among the three carriage places regarding only sperm morphology (p = 0.028) but no other sperm parameters (Table 2). The duration of smoking was significantly shorter in participants who carry their cell phone in a handbag (p = 0.034).

Duration of wireless internet use

When we compare the wireless internet users regarding the duration of internet usage, there were a significant decrease of total motile sperm count and progressive motile sperm count (p = 0.032 and p = 0.033; respectively; Table 3). Similarly, the duration of smoking was significantly shorter in Group B than the other groups. In addition to that, there were no significance among the semen parameters regarding the wired internet group (p = 0.128).

Type of internet usage

Total motile sperm count and progressive motile sperm count were lower in the wireless internet usage group compared with the wired internet usage group (p = 0.009 and p = 0.018; respectively). Type of internet connection does not affect the other sperm parameters (Table 4).

There was a negative correlation between the cell phone usage duration and the total sperm count (r = −0.064, p = 0.04). Similarly, there was also a negative correlation between the wireless internet usage duration and the total sperm count (r = −0.089, p = 0.019). Otherwise there were no significant correlations among the other four main question branches (cell phone usage time, cell phone carriage habits, wireless internet usage time. and internet connection type) and sperm parameters.

Leucocyte count from the semen analyses were normal in all of the patients.

Discussion

Even though there are possible harmful effects from cell phones and wireless internet, we use them frequently in our lives [4]. Kumar et al. [9] have shown that 10 GHz

Table 2 Comparison of the demographic data and sperm parameters among the mobile phone carrying habits groups.

	Trouser pocket (n = 767)	Handbag (n = 106)	Jacket pocket (n = 158)	p*
Age (y)	30.4 ± 6.25	33.3 ± 5.9	31.8 ± 5.8	0.671
BMI (kg/m^2)	26.1 ± 3.6	27.5 ± 4.1	26.7 ± 4.6	0.150
Smoking (y)	3.46 ± 5.55	1.7 ± 5.53	4 ± 6.53	0.032
Volume	2.9 ± 1.37	3.08 ± 1.4	3.02 ± 1.38	0.973
TSC (million)	39.1 ± 31.1	45 ± 31.6	40.3 ± 27	0.256
TMS (million)	56.5 ± 60.1	63 ± 48.6	53.6 ± 49.1	0.168
PMS (million)	43.8 ± 51	49.6 ± 41.4	41.9 ± 41.1	0.538
Morphology	2.72 ± 1.81	3.18 ± 2.47	2.43 ± 1.38	0.034

*One way analysis of variance was performed. A p value < 0.05 between all groups was considered significant.

Table 4 Comparison of the demographic data and sperm parameters between the internet usage (wired or wireless) groups.

	Cable (n = 350)	Wireless (n = 681)	p*
Age (y)	30.8 ± 6.38	30.9 ± 6.1	0.279
BMI (kg/m^2)	26 ± 3.76	26.5 ± 3.9	0.646
Smoking (y)	3.68 ± 5.83	3.24 ± 5.7	0.281
Volume	2.92 ± 1.25	2.98 ± 1.43	0.064
TSC (million)	42 ± 32.3	38.8 ± 29.6	0.054
TMS (million)	62.7 ± 61.3	53.6 ± 55.2	0.009
PMS (million)	48.9 ± 50.3	41.1 ± 47.7	0.018
Morphology	2.82 ± 1.72	2.67 ± 1.88	0.182

*Student t test performed. A p value < 0.05 between groups was considered significant.

electromagnetic fields resulted in DNA damage of sperm via micronuclei formation due to the oxidative stress. To the best of our knowledge, there are limited numbers of human and animal studies with respect to cell phone effects on testes and semen parameters [4,7,10,11]. Additionally, not much study has been performed on the impacts of wireless internet and cell phones on male fertility. Therefore, the present study aimed to determine the effects of cell phone and wireless internet usage habits on human sperm parameters. For this purpose, an anonymous questionnaire was applied to a total of 1082 healthy men who attended our urology clinic for semen analysis, and only 1031 patients were included in the study. According to their answers regarding their habits of carrying mobile phones, cell phone usage duration, and wireless usage, participants were divided into four different groups.

In our previous study, we compared the effects of the standby mode or the active mode of the cell phone on rat testes, and we detected significant apoptotic rates in testicular tissue in the active cell phone group compared with other groups [10]. Mailankot et al. [11] have shown a decrease in sperm motility in RF-EMR exposed rats for 28 days. Wang et al. [12] have indicated that Leydig cells were the most susceptible cells to RF-EMR exposure. However, rat studies could have some problems due to their small testis size, the nonpendulous structure of the scrotum, and they are also less affected by environmental factors in laboratory conditions [13].

There are some human studies which have shown the effect of cell phones on semen parameters. In one study, it has been indicated that semen parameters decreased when the cell phone was carried in the pocket of trousers near the testes [14]. Similarly, Fejes et al. [7] have investigated that habits of carrying a mobile phone and speaking durations were negatively correlated with rapid progressive sperm count. In another study, Agarwal et al. [4] has found that when cell phone usage duration increased, the quality of sperm including the sperm count, the motility, and the viability decreased, and the normal sperm morphology changed in 361 men. Contrary to these two reports, we did not find any effect of cell phone usage duration and habits of carrying a mobile phone on the total sperm count, the motility, the semen volume, and the normal sperm morphology. However, in our study, there were only negative correlations between cell phone usage duration and the total sperm count.

Turkish Telecommunication and Information Technology Agency declared that the daily usage of internet is nearly 6 hours in Turkey [15]. Therefore, according to us, Wi-Fi usage needs to get more attention than cell phone usage due to its higher frequency ranges and longer exposure times [16]. Even though there are some studies performed on the effects of RF-EMR and cell phones on male fertility, there is not so much scientific data about the association between Wi-Fi internet usage and male fertility [17]. Unlike other RF-EMR sources, devices such as laptops and tablets usually stay near the reproductive organs. In some studies, investigators did not find any histopathological or mutagenic alterations in mouse testes due to 2.45 GHz RF-EMR [13]. However, Atasoy et al. [17] have demonstrated that continuous Wi-Fi exposure with 2.45 GHz affected the testes of growing rats and led to DNA damage. Moreover, in an *in vitro* study performed with the motile spermatozoa from 29 healthy donors, motile spermatozoas were split and divided in two aliquots and they were exposed to a Wi-Fi computer for 4 hours. According to results of this study, the Wi-Fi group showed a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation [18]. In our study, the total motile sperm and progressive motile sperm were decreased in a group who used a wireless internet compared with ones who used the wired internet. Also, there was a statistically significant decrease in total motile sperm and progressive motile sperm with the increased wireless internet usage duration. In addition, there was a negative correlation between the wireless internet usage duration and the total sperm count.

Smoking is another factor for decreased sperm quality [19]. The polycyclic aromatic hydrocarbons induce a proapoptotic mechanism in female embryos and male germ cells [20]. However, there is still a debate about whether smoking is harmful for sperm parameters [21,22]. Even most studies have showed that smoking mostly affected semen quality such as sperm progressive motility, we did not detect any correlation among smoking and the sperm volume, the total sperm count, and the total motile sperm count. Also the discrimination of the smoking habits among the questionnaire subgroups were irregular, such as mean years of smoking decreased while the wireless internet usage time increased so that we could not say any exact opinion about the relation between smoking and the sperm parameters.

The limitations of the present study are the absence of control individuals who do not use cellular phones which is hard to find in the present technological era. Besides, environmental factors have an impact on the exposure levels. Therefore, the difference between experimental studies and social studies is inevitable.

Conclusion

The possible effects of RF-EMR due to cellular phone and Wi-Fi usage should be investigated by researchers in more detail because the harmful effects should be proven instead of just implying the possible detrimental effects. Our findings display contrast results when we compared

them with existing information and beliefs. We have not seen any difference between sperm parameters and cell phone and wireless internet usage. Larger population based studies combined with the laboratory results are needed to reach a definitive conclusion.

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